
LIQ - 60 User Manual



Trademarks

Windows and Microsoft are registered trademarks of Microsoft Corporation. Digi is a registered trademark of Digi International Inc. All other trademarks are property of their respective owners.

Copyright

© CHK GridSense Pty. Ltd. 2011, 2012

The material presented in this manual is copyright protected by CHK GridSense Pty. Ltd. 2011. Any reproduction in whole or part for any purpose without the prior written consent of GridSense Pty Ltd is strictly prohibited. Information in this document is subject to change without notice.

Contents

1	Safety	1
1.1	Hazard Assessment	1
1.2	Working on energised conductors and equipment	1
1.3	Equipment safety	1
2	Introduction to the LineIQ device family	2
2.1	Glossary	4
2.2	Implementation Scenarios	6
2.3	System Functionality	6
2.4	LIQ-60 Conductor Mounted Sensor overview	7
2.4.1	LIQ-60 Design	8
2.4.2	LIQ-60 Sensing	8
2.4.3	Operation Modes	9
2.4.4	Visual Indicators	11
2.4.5	Power Factor Calculation	15
2.5	LIQ-Gateway Overview	17
2.6	LIQ-LocalLink Overview	18
3	Initial setup	19
3.1	LIQ-LocalLink installation	19
3.1.1	For Microsoft Windows 7	19
3.1.2	For Microsoft Windows XP	19
3.2	LIQ-60 setup	20
3.2.1	Switching on the LIQ-60	20
4	Configuration	21
4.1	LIQ-60 configuration	21
5	Commissioning	21
5.1	Commissioning the LIQ-60	21
5.1.1	Pre-commissioning check of the LIQ-60s	21
6	Installation and removal	22
6.1	LIQ-60 installation	22
6.1.1	Pre-installation	22
6.1.2	Mounting	22
6.1.3	Post-installation checks	22
6.1.4	Removal	23
7	Power Systems	23
7.1	LIQ-60 Battery	23
7.2	Solar Panels	23
7.2.1	Solar Panel orientation	23
7.2.2	Adjusting the solar panel on the LIQ-60	25

Appendix A – LineMan	26
A.1 LineMan Overview	26
A.2 Setting up an LIQ-LocalLink	26
A.3 Connecting to the CMS with LineMan	27
A.4 Displaying LIQ-60 Status/Summary	27
A.5 Configuring an LIQ-60	29
A.6 CMS Data Download	30
Appendix B – Window XP Installation	31
Appendix C	34
C.1 LIQ-60 specifications	34

1 SAFETY



If you do not understand any instructions in this manual, please ask someone to assist you.



For safety reasons, use only GridSense accessories specifically designed for use with these products, or accessories that have been approved by GridSense. The use of any other manufacturer's equipment is NOT recommended, will void the warranty and may cause safety hazards.

The LIQ-60 Conductor Mounted Sensors are intended to be used on high voltage energised conductors or equipment. Personnel using equipment on energised lines must be authorised by the relevant regulatory bodies to carry out such work and must have appropriate training.

The information given in this document is given as a guide only. It is the user's responsibility to ensure that correct and safe procedures are followed at the actual worksite. GridSense offers no warranty or indemnity for accidents that may occur when following these instructions.



If the LineIQ products and accessories and associated equipment are used in a manner other than that specified in this manual, the protection provided by the equipment may be impaired.

1.1 Hazard Assessment

Prior to installing the equipment, the operator must carry out a worksite, pre-job hazard assessment to identify the safety and environmental needs. This must be done prior to commencing work and prior to recommencing work after leaving and returning to the worksite. As a minimum, this hazard assessment should:

- Identify possible hazards and risks
- Identify the safety needs of the job
- Identify the correct procedures, practices and equipment
- Eliminate unsafe conditions and actions from the worksite
- Identify the need for personal protective equipment
- Inspect equipment before use.

Prior to using an LIQ-Gateway, you should check the following:

- The sheaths of all cables are secured and undamaged
- Plugs and connectors are properly connected and serviceable.
- There should also be an ongoing risk assessment during the job.

1.2 Working on energised conductors and equipment

For the correct and safe use of this equipment, it is essential that all operating personnel follow appropriate safety procedures. Check your employer or relevant regulatory body's rules for working with energised equipment.

1.3 Equipment safety

The LIQ-Gateway and associated equipment should be maintained and regularly tested to make sure the equipment is in good order.

2 INTRODUCTION TO THE LINEIQ DEVICE FAMILY

The LineIQ monitoring system allows electricity utilities and other operators of high and medium voltage overhead conductor distribution and transmission lines to monitor and respond to faults and load changes on the supply grid. The monitoring system consists of Conductor Mounted Sensors (CMS), data collators, and remote or on-site PC-based analysis and control software. The LineIQ system links to existing SCADA or Distribution Management systems. The CMS communicate with the data collators (LIQ-Gateways) using short range radio. The LIQ-Gateway and CMS can also communicate with on-site PCs (e.g. laptop) using short range radio, when an LIQ-LocalLink is connected to the PC. The LIQ-Gateways in turn communicate with control rooms via a cellular modem or long range radio links, and can use a variety of different communication standards.

Figure 1 shows a typical implementation of LineIQ monitoring equipment.

The LIQ-60 CMS detect and store network events and also monitor load currents, power factor, conductor voltage, and ambient and conductor temperatures.

Events such as faults, momentary interruptions, sustained interruptions and restorations are radioed to the LIQ-Gateway as unsolicited events, which in turn are sent on to the SCADA and control centre. Ongoing measurements such as load currents, conductor voltage, and ambient and conductor temperatures are periodically downloaded to the LIQ-Gateway, which collates the information and sends it to the control centre.

The LIQ-60s are installed on energised lines. They are battery and solar powered for long term continuous monitoring. They can be configured and have their firmware upgraded wirelessly using the same license-free short range radio link (RF link) which is used to download data. Hence, there is no need to remove the LIQ-60s from the conductors after they have been installed.

LIQ-Gateways function as Remote Terminal Units (RTUs) and are mains powered or battery/solar powered, depending on location and supply availability. Transmission of load log data from the LIQ-60 to the LIQ-Gateway occurs during a status check which is periodically initiated by the LIQ-Gateway. This data is then transmitted by the LIQ-Gateway to the remote monitoring system (e.g. SCADA) or is accessed on demand using LineMan or SCADA via a variety of supported protocols, for example DNP3, IEC 61850 or Web services.

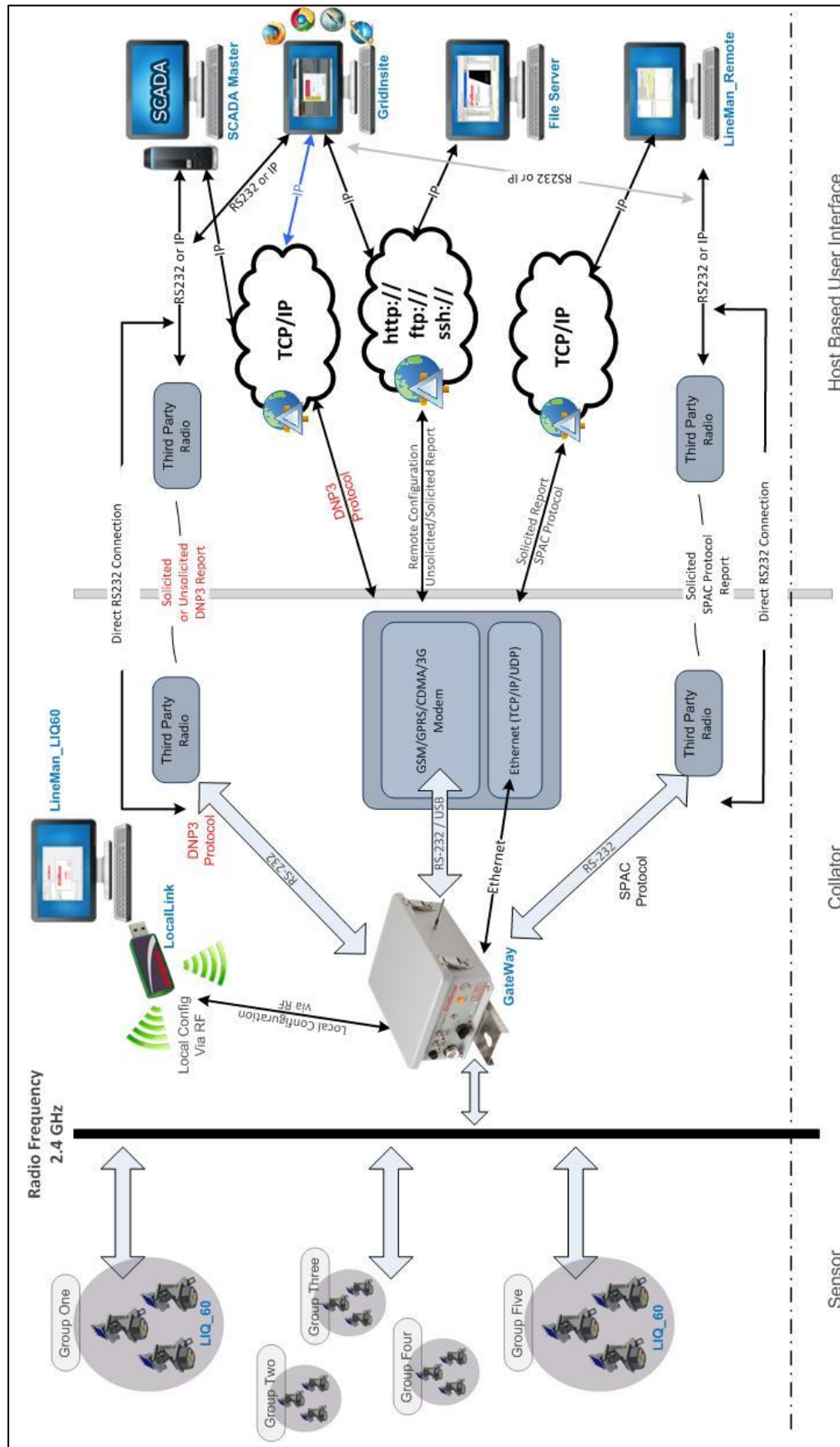


Figure 1: Typical Implementation of LineIQ Components

2.1 Glossary

Term	Meaning
CMS	Conductor Mounted Sensor which detects events on a conductor and logs voltage, current and temperature for periodic downloading. The LIQ-60 is a CMS.
Commission	Putting equipment into use for the first time. Follows after configuration.
Configure	The process of setting up equipment to perform a designated task. In this manual refers mainly to firmware. Follows after set-up.
DPF	Displacement Power Factor. A measure of the phase difference between the voltage and current. { $DPF = \cos(\phi)$ } Ideally ϕ should be 0 degrees, so $DPF = 1$.
DTS	Date & Time Stamping
Event Profile Recording Period	The time (e.g. 1 minute) after an event has been detected and during which the LT-60 records current and power profiles.
Fast Filter	A 5 sec. average value filter, applies to both current (I) and voltage (V).
FP	Fault Path: a high current event
HV	High Voltage
IED	Intelligent Electronic Device
LED	Light Emitting Diode
LI	Long Interruption: a loss of power on a conductor for at least one minute.
LIQ-Gateway	The Pole Attached Collator, which receives and collates data from CMS
LIQ-LAN	A local area network consisting of a PC (Laptop) with LIQ-LocalLink for communications, an LIQ-Gateway & its associated LIQ-60.
LIQ-	A USB-based radio. Used for

Term	Meaning
LocalLink	communications between a PC and the LIQ-Gateway and LIQ-60s in an LIQ-LAN.
Loss of volts	When a CMS detects no voltage on the conductor.
LV	Low Voltage
ms	milliseconds
Permanent Fault	Fault detection with loss of supply detected after the end of the event profile recording period.
PMS	Pole Mounted Sensor (as distinct from a CMS).
P-P	Peak to Peak. A measure of a waveform's amplitude (absolute, unlike RMS) $P-P \approx 2.38V_{RMS}$
PR	Power Return: return of power after a Long Interruption (LI).
PRT	Platinum Resistance Thermometer. Two are mounted in each LIQ-60 to measure conductor and ambient temperature.
Return of volts	When a CMS detects a return of voltage on the conductor after a fault condition.
RF	Radio Frequency
RMS	Root Mean Square (An amplitude of a measurable value, e.g. Voltage, written V_{RMS}). The square root of the mean over time of the square of the waveform.
RTC	Real Time Clock.
RTU	Remote Terminal Unit. In SCADA terminology, the LIQ-Gateway is an RTU. It collates information from sensors to be sent to centralised control units.
SCADA	Supervisory Control And Data Acquisition. Usually a computer system that monitors and controls industrial or facility-based

Term	Meaning
	processes.
Self-clearing fault	Fault current detected with no loss of supply during the event profile recording period.
Set up	The process of setting up equipment to perform a designated task. In this manual refers mainly to hardware and installation, usually precedes configuration.
SI	Short Interruption: brief (less than one minute) loss of power on the conductor.
SLA Battery	Sealed Lead Acid Battery. The power storage for the LIQ-60 and LIQ-Gateway.

Term	Meaning
Slow Filter	A 10-day non-linear average reflecting the highest value of current and voltage over the weekly load cycle.
TPF	True Power Factor. The ratio of the real power flowing to the load, to the apparent power in the circuit.
Transient Fault	Fault detected with a loss and return of supply seen during the event profile recording period.

2.2 Implementation Scenarios

A possible implementation scenario is shown in Figure 2. This is a permanent configuration used for continuous monitoring of power lines using LIQ-60s, LIQ-Gateways and LineMan communications software.

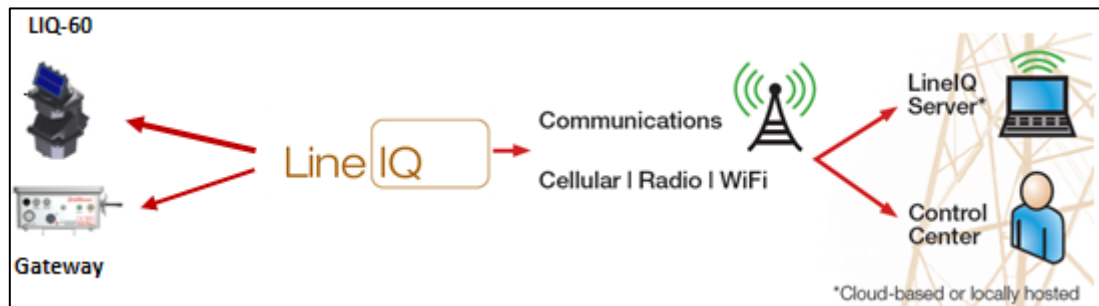


Figure 2: An installation of GridSense devices as part of a permanent monitoring configuration.

2.3 System Functionality

With regards to communication among the components in the LineIQ family, the LIQ-60s and the LIQ-Gateway (and, if present, a laptop PC using an LIQ-LocalLink), form a local area network, the LIQ-LAN. This network's communication is based on low power RF.

The LIQ-Gateways which communicate with remote control rooms or SCADA systems, can be viewed as a wide area network, using any of a range of protocols, such as DNP3, IEC 61850 or Web services.

2.4 LIQ-60 Conductor Mounted Sensor overview

The LIQ-60 Conductor Mounted Sensor is a programmable Medium and High Voltage (MV/HV) power grid logger used to detect and log fault conditions, and to record load information, voltage and conductor and ambient temperatures on power distribution networks.

Figure 3 shows the LIQ-60 Conductor Mounted Sensor.



Figure 3: The LIQ-60 Conductor Mounted Sensor.

The LIQ-60 is installed live on a bare overhead conductor and detects and logs disturbance events such as fault currents or loss and return of voltage.

Each event is date and time stamped (DTS) and recorded to non-volatile memory for later analysis. High intensity LEDs are provided to indicate line and fault status to maintenance crews.

The LIQ-60 can be configured to calculate and store time-averaged load current, i.e. load logging. The Log Average interval can be selected in the range from 2 to 60 minutes. Ambient and conductor temperatures are also recorded at the same Log Average interval.

The LIQ-60 can also measure and record Displacement Power Factor (DPF) values at the Log Average interval.

This logged information is downloaded on demand to an LIQ-Gateway unit which periodically requests data from all the LIQ-60s that are part of its LIQ-LAN.

2.4.1 LIQ-60 Design

The LIQ-60 uses a sprung clamp to attach to bare conductors between 5mm ($\frac{3}{16}$ ") and 32mm ($1\frac{1}{4}$ ") in diameter. It is designed to be mounted on the line by using a "hot stick" as commonly used by electricity utilities.

The LIQ-60 is powered by a sealed lead acid battery which provides continuous long term power for remote reporting of events and historic load data. A solar panel mounted on top of the LIQ-60 charges the battery.

2.4.2 LIQ-60 Sensing

The LIQ-60 measures conductor current, conductor voltage, ambient and conductor temperature and calculates Displacement Power Factor.

Current

Current is sensed with a Rogowski coil, which is automatically closed around the conductor during the installation process. The inherent nature of a Rogowski coil (which does not have a magnetic core) means that the coil does not saturate, allowing the LIQ-60 to measure currents over a wide dynamic range, from 1 A up to 25 kA.

Voltage

Two options are available:

Standard option: the standard "out of the box" LIQ-60 measures voltage by sensing the capacitive current which flows between the LIQ-60 body and ground/earth. This capacitance varies with atmospheric conditions (temperature, humidity, air pressure, rain, snow etc.) and also with the physical arrangement of the LIQ-60 and nearby grounded/earthed structures and energised conductors. This means that it is not possible to make accurate voltage measurements. The LIQ-60 therefore scales the voltage measurements so that a reading of 100% corresponds to the normal energised conductor voltage.

High accuracy: the second option is to purchase a voltage sensor from GridSense which connects electrically and mechanically between the LIQ-60 and an earth point. This enables an accurate reading of the line voltage.

Temperature

Conductor and ambient temperatures are sensed using platinum resistance thermometers (PRT). One PRT is automatically placed in contact with the overhead conductor when the LIQ-60 is installed. Ambient temperature is measured using a shaded PRT mounted on the upper part of the LIQ-60 housing.

Temperatures are sampled regularly, then averaged and recorded at the Log Average Interval.

Power Factor

The voltage and current data are low pass filtered to eliminate harmonic information, and then the zero crossings of the voltage and current signals are detected and processed over a one minute period. This allows calculation of the phase angle of the current with respect to the voltage. The sign of phase angle measurements are taken into account, so that the measurements can be assigned to the correct quadrant.

Displacement Power Factor (DPF) is calculated from the measured phase angle, ϕ , where $DPF = \cos(\phi)$. For voltages and currents with low distortion, as is normally the case on high voltage systems, this calculated DPF is a good approximation to the True Power factor (TPF).

Power factor measurements are averaged and recorded at the Log Average Interval. Recorded data includes phase angle, sign (leading or lagging) and DPF.

See section *2.4.5 Power Factor Calculation* for a more detailed description of the power factor calculations.

2.4.3 Operation Modes

For the majority of time that the LIQ-60 is installed it will simply be monitoring and storing its input values. There will be minimal radio communications during this time, restricted to periodic status requests from an LIQ-Gateway, unless initiated by an external device such as a Laptop PC using LIQ-LocalLink. Should an event such as a power outage occur, there will be increased radio communications when the event is detected.

Normal Operation

During normal operation the LIQ-60 continually samples voltage, current and temperatures.

The raw sample points (measured at 600Hz for voltage and current) are stored in a circular buffer, so that once an event is detected, the LIQ-60 can "look backwards in time" and recover pre-fault information.

RMS voltage and current readings are calculated from the raw sample points. These RMS values, which are updated at the supply frequency (50Hz or 60Hz) are used as inputs to the event detection algorithm.

If load logging is enabled, the current readings are averaged and stored at the end of each Log Average period.

The voltage and current readings are processed by Fast Filters to provide input signals for the event detection algorithm, in addition to the per-cycle values.

The outputs of the voltage and current Fast Filters are further filtered by non-linear Slow Filters. These filters have a decay time constant of approximately 10 days, but a much faster attack time constant. The output of the Slow Filters provides a good representation of the normal conductor load profile. The Slow Filter outputs also provide inputs to the event detection algorithm.

Average conductor and ambient temperatures, as well as phase angle and power factor data are stored at the Log Average interval.

Event Classification

LIQ-60s incorporate a sophisticated event detection algorithm which analyses voltage and current data and reports the following activity occurring on the conductor:

- Fault Path (FP) – a high current event.
- Short Interruption (SI) – a brief (less than one minute) loss of power on the conductor.
- Long Interruption (LI) – a loss of power on the conductor for at least one minute.
- Power Return (PR) – return of power after a Long Interruption (LI).

Some of these activities can occur together.

For example, an LIQ-60 mounted on a conductor upstream (i.e. on the generator side) of a fault which results in a permanent outage will report a FP-LI event, whereas an LIQ-60 mounted downstream (i.e. on the load side) of that fault will report a LI event only, because it will not see the fault current. After power is restored, both LIQ-60s in this example will report a PR event.

A second common example is where the system protection (recloser) operates and clears the fault. In this case, the LIQ-60 upstream of the fault will report a FP-SI event, whereas an LIQ-60 downstream of the fault will report a SI only. Since power has only been briefly interrupted, a PR event will not occur.

Power Status

The LIQ-60 event detection algorithm analyses the Power Status of the conductor as follows:

- If the previous Power Status is OFF, then the Power Status changes to ON if either voltage OR current is PRESENT.
- If the previous Power Status is ON, then the Power Status changes to OFF if both voltage AND current are ABSENT.

Event Triggers

An Event commences when one of the following trigger occurrences is detected:

1. High Current 1 – at least 2 cycles of current that are more than twice the normal conductor load profile, accompanied by a 25% change (reduction or increase) of the voltage.
2. High Current 2 – at least 2 cycles of current that are more than 5 times the normal conductor load profile. The voltage reading does not influence the detection of this type of event.
3. High Current 3 – when the current exceeds a fixed (absolute) value. Contact your nearest GridSense support centre for further information.
4. High Current 4 – when a rapid change in current exceeds a selected delta value. (In other words when the difference between normal and detected current exceeds a selected value.) Contact your nearest GridSense support centre for further information.
5. Loss of Power.
6. Power Return.

When an event is detected, the LIQ-60 commences a one minute "Event Profile Recording Period". The event detection is re-triggerable so the event profile recording period can be extended should a higher priority event occur.

For example, if a Power Return is detected within one minute after a Loss of Power, then the event profile recording period is started again, so that the event profile recording period will be longer than one minute. If a high current is then detected, the event profile recording period will again be extended.

Event Recording

Event Mode

The LIQ-60 enters Event Mode when one of the Event Triggers mentioned above occurs.

High Current trigger characteristics

If the event profile recording period commences with a high current trigger, the LIQ-60 also records snapshots of the voltage and current waveforms.

Each of these snapshots is 200 ms long, corresponding to 10 cycles for a 50 Hz supply and 12 cycles for a 60 Hz supply. The trigger point is set at 60 ms, so the first 60 ms of each record is the pre-event waveform, and the final 140 ms are the post event waveforms.

Characteristics for all triggers

For the full length of the event profile recording period (at least one minute), the LIQ-60 records a current profile.

An initial current value is recorded, along with its time of occurrence. The current is then monitored on a cycle by cycle basis. If the current changes by more than 50%, a new current (and its time of occurrence) is recorded. This process continues until the end of the event profile recording period. This recording method allows a detailed time plot of the conductor current to be constructed. This plot has sufficient detail to enable the sequence of current changes caused by recloser operation to be reconstructed.

The LIQ-60 also stores time stamped changes in power status, which allows a time plot of power status to be constructed.

Types of Faults

- Self-Clearing Fault – A High Current trigger occurred but Power remained unchanged.
- Transient Fault – A High Current trigger occurred and Power goes OFF briefly but is restored before the end of the Event Profile Recording Period.
- Permanent Fault – A High Current trigger occurred and Power goes OFF and remains OFF at the end of the Event Profile Recording Period.

LIQ-60 Load Log retention in memory

If the load log memory fills up, it operates as a circular memory, overwriting the oldest data so that the latest log data is always retained. This does not affect event storage memory.

2.4.4 Visual Indicators

Visual indications of status and event information are provided by three high intensity LEDs mounted on the base of the LIQ-60, and therefore visible from the ground when the LIQ-60 is installed on an overhead conductor.



Figure 4: LIQ-60 base panel

LIQ-60 Status LED

During sensing mode, this amber LED indicates that the LIQ-60 is powered on by flashing briefly once every 30 seconds. At other times (start-up etc.) this LED provides other information. See Table 1 on page 14 below.

LIQ-60 Fault LEDs

During sensing mode, these red LEDs indicate that the LIQ-60 has sensed a fault in the overhead conductor. These LEDs also have other functions. See Table 1 on page 14 below. Both Fault LEDs will operate in parallel. Future upgrades will provide for fault direction indication.

Commissioning Status

After an LIQ-60 is powered up, it must be configured and commissioned before it becomes active. In order to allow easy site installation by line crews without access to LineMan software, LIQ-60s are provided with an auto-commission feature.

An auto-commission is performed one hour after an LIQ-60 is powered up. This period is indicated by a slow (one second) flashing of both red LEDs.

Line Status

The amber LED indicates line status. The number of flashes emitted every 30 seconds indicates the line status, as detailed below:

- One amber flash every 30 sec. indicates that the line is energised (voltage is present) and is carrying current.
- Two amber flashes every 30 sec. indicate that the line is energised (voltage is present) but is not carrying current.
- Three amber flashes every 30 sec. indicate that neither voltage nor current are present on the line.

Fault Indication

Only one red LED at a time will flash during a fault condition.

The LED produces a distinctive pattern of flashes every 10 sec. as follows:

- One red flash indicates that a self-clearing fault has been detected.
- Two red flashes indicate that a transient fault has been detected.
- Three red flashes indicate that a permanent fault has been detected.

Firmware Upgrades

LIQ-60 firmware can be upgraded using the LIQ-LocalLink and LineMan. During this process the LEDs are used to indicate status as follows:













- Amber LED – continuous fast flashing (10Hz) indicates that firmware is being uploaded to the LIQ-60 buffer.
- Red LEDs – continuous fast flashing (10Hz) indicates that there has been an error during the firmware upload process into the buffer.

Once the firmware is successfully uploaded into the buffer, the LIQ-60 copies the new firmware into flash memory. This process is indicated by the amber LED being permanently on.

At the end of the firmware upgrade process, the LIQ-60 will restart.

The LIQ-60's LED indicator flash patterns

The LEDs are also used to indicate other operational statuses. The various flash patterns are summarised in Table 1.

Indication	LIQ-60 LED Flash patterns		Meaning
Line status	Amber LED (1, 2 or 3 flashes repeated every 30 sec)	 (single)	Voltage and Current present.
		 (double)	Voltage but no Current.
		 (triple)	No Voltage and no Current.
Fault detected (1 red LED on side of fault)	Red LED (1, 2 or 3 flashes repeated every 10 sec)	 (single)	FP self-clearing fault sensed.
		 (double)	FP-SI transient fault sensed with short interruption.
		 (triple)	FP-LI permanent fault sensed with long interruption.
Ready for installation / commissioning	Both Red LEDs flash once every sec.	 (single)	LIQ-60 awaiting commission. Auto-commission will occur within 1hr of start-up (or reset) if not done manually.
	& Amber LED triple flash every 30 sec.	 (triple)	Amber LED is indicating LIQ-60 is not sensing Voltage or Current.
Firmware upload	Either Amber or both Red LEDs (Fast flash, 10Hz)	 (very rapid)	Firmware upload into buffer in progress.
		 (very rapid)	Error during firmware upload into buffer.
CPU upgrade	Amber or all 3 LEDs	 (steady)	Firmware transfer from buffer to flash ROM.
		 (steady)	LIQ-60 awaiting synchronisation signal from LIQ-Gateway. (All three LIQ-60s on a feeder get synchronised prior to Power Factor measurements).



LED Indicator	Description
	Amber LED
	Red LED

Table 1: LIQ-60 indicator LED flashing patterns

2.4.5 Power Factor Calculation

2.4.5.1 Overview

This overview gives a brief introduction to Power Factor values, i.e. what is meant by Displacement Power Factor and True Power Factor.

See *Appendix A – LineMan* which explains how to use LineMan to configure an LIQ-60 to measure Displacement Power Factor.

What Information is provided

The LIQ-60 records the phase angle between the fundamental (50/60Hz) voltage and current waveforms, from which the Displacement Power Factor (DPF) can be derived. This information is made available in the following formats:

- Instantaneous DPF and phase angle (including lead/lag) of the line is returned when the LIQ-60 status is queried. These parameters are averaged over approximately 1 minute and updated every minute.
- Average DPF and phase angle (including lead/lag) are logged for each load log interval. This interval can be set to be between 2 and 60 minutes.

Meaning of Power Factor Values

The LIQ-60 will record power factor on power systems operating in all four quadrants of power flow.

Positive DPF indicates net energy flow is from source to load and negative DPF indicates net energy flow is from load back to the source.

Positive phase angles indicate current is leading voltage (capacitive load) and negative phase angles indicate current is lagging voltage (inductive load).

Displacement vs. True Power Factor

Displacement Power Factor (DPF) is defined as $\cos \phi$ where ϕ is the phase angle between fundamental (50/60Hz) voltage and current waveforms, whereas True Power Factor (TPF) is defined as the ratio of Real Power (in watts) to Apparent Power (in VA). In the case of sinusoidal waveforms, $DPF = TPF$, however they are no longer equal for non-sinusoidal waves such as those containing harmonics.

The LIQ-60 measures DPF, thus consider harmonic content before inferring the TPF from LIQ-60 readings. With normal levels of harmonic content on typical power lines the difference between DPF and TPF is small and usually will be negligible, however if you suspect high harmonic content, a harmonic study should be performed if knowledge of TPF is critical.

2.4.5.2 Defining Load and Source Directions

To determine how to correctly record power factor the LIQ-60 needs to know which way it is mounted on the power line, i.e. which direction is towards the source and which is towards the load. Under most conditions with a single generation source this will be easy to define. In the case of power lines with multiple generation sources you must choose which direction to call the 'source' and which the 'load'.

LineMan provides an interface to set the load direction of the LIQ-60, as determined by the direction of the reference arrow on the bottom of the LIQ-60.

Field Calibration - Compensating for Effects of Adjacent Conductors

The LIQ-60 does not normally have a ground reference, so it uses the electric field created between the line and ground to establish the voltage zero crossing. This field can be skewed by adjacent conductors, so LineMan provides a wizard to compensate for those effects. The wizard is run once for each set of 3 LIQ-60s on a single feeder. It cannot be run on a single LIQ-60.

2.5 LIQ-Gateway Overview

The LIQ-Gateway is an intelligent Remote Terminal Unit (RTU) used in conjunction with the LIQ-60 conductor mounted sensor. The Gateway collates events and enables remote unsolicited fault and outage event reporting for network reliability applications. It provides detailed fault profiles for fault location analysis, modelling and scenarios, as well as system load information for planning, line balancing and asset utilisation applications.

The Gateway is a pole attached collator mounted within radio range of the CMS and can be integrated into remote SCADA system via DNP3, IEC 61850 or Web services protocols. Communication with external systems is usually achieved using a GridSense supplied communication module. If for technical reasons this does not provide coverage in a specific area, other modems that are supported by GridSense can be used.

Event data is transferred to the LIQ-Gateway shortly after capture by the CMS devices. Load log data (conductor current, voltage, conductor and ambient temperatures and power factor) is requested by the LIQ-Gateway from the CMS at regular, user selected intervals. In addition, a system "Health Check" at a user defined interval, is initiated by the Gateway independently of events. The Gateway initiates communications with each CMS to download all log data and health records (battery voltage, solar charge current etc) to the Gateway memory. This information can be remotely accessed via LineMan Remote, or accessed by SCADA.

The LIQ-Gateway can be AC or battery/solar powered, depending on power requirements and the availability of mains power. Power consumption is minimised by powering up the communication systems, i.e. LIQ-LAN and cellular modem or utility radio, only when required.

The LIQ-Gateway has a combined connector / indicator panel. This comprises connectors for AC mains and solar power input, an Ethernet connector, radio antenna and cellular antenna, and two LEDs used as visual status indicators.

2.6 LIQ-LocalLink Overview

The LIQ-LocalLink is a licence-free radio modem that plugs into a USB port on a laptop or PC. It uses the IEEE 802.15.4, 2.4 GHz communications standard, enabling it to communicate with a similar radio inside an LIQ-60 or LIQ-Gateway.

The operating range depends on on-site conditions, the recommended operating range is 30m (100ft) using an internal omnidirectional antenna.

The kit comes with a magnetic mount, which can be attached onto any Ferromagnetic material.



Figure 5: The LIQ-LocalLink modem

3 INITIAL SETUP

3.1 LIQ-LocalLink installation

3.1.1 For Microsoft Windows 7

The drivers for the LIQ-LocalLink type modem are included in Microsoft Windows 7.

1. Plug the LIQ-LocalLink into a USB port on a laptop.
2. The first time that an LIQ-LocalLink is plugged into a laptop's USB port, the Microsoft Windows driver installation dialog will appear onscreen.
3. Follow the prompts to install the drivers.
4. Take note of the assigned COM Port number (in the example below COM4) as this will be required when setting up the LineMan interface.

(This example installation was done on Windows 7 Pro 32-bit SP1.)

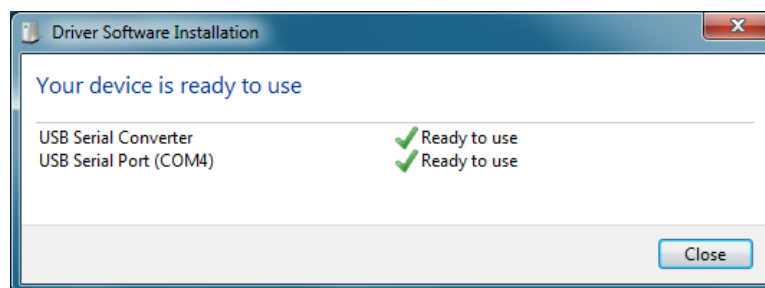


Figure 6: Windows 7 dialog after LIQ-LocalLink modem installation

5. To determine the COM Port connection, access the Device Manager(**Control Panel** → **System** → **Device Manager**) and expand the selection "Ports", the selection USB Serial Port will identify the correct COM Port number.

3.1.2 For Microsoft Windows XP

Please refer to Appendix B for Windows XP installation.

3.2 LIQ-60 setup

Before the LIQ-60 is configured, its battery needs to have sufficient charge. The LIQ-60 is delivered with a fully charged battery, but it will discharge during storage.

The battery voltage can be determined with LineMan. Run the LineMan software application and scan for all LIQ-60 CMS within range. Available devices will be displayed under the Line Tracker Information window. Click on the device interest and click on Summary. If the battery voltage is less than 2.0V then it should be charged before installation. It is recommended that you use a GridSense LIQ-Charger.

Alternatively, the battery can be charged using the LIQ-60 solar panel. However, charging a completely flat battery may require optimal sunlight for up to 50 hours.

3.2.1 Switching on the LIQ-60

The LIQ-60's power switch is located on the bottom panel. It is a rotating switch that turns through 90 degrees between the OFF and ON positions, as indicated by arrows.

1. Rotate the switch clockwise to the ON position. In the ON position it will be in line with the 2 (red) fault indicating LEDs.

When the unit is powered on the red and amber LED's will start a flash sequence. The red LED will flash 8 times followed by 8 flashes from the amber LED.

After the start up sequence, the red LEDs will illuminate once every second indicating that the unit is in a non-sensing state, awaiting commissioning. Prior to commissioning the amber LED will flash 3 times every 30 seconds. If after one hour the LIQ-60 has not been manually commissioned, it will commission itself automatically.

Refer to Table 1 on page 14 for an explanation of LED status and fault indication sequences.

4 CONFIGURATION

Before the LIQ-Gateway and LIQ-60s are mounted and commissioned, they need to be configured. Configuration of the LIQ-60 and the LIQ-Gateway is performed using LineMan and an LIQ-LocalLink.

4.1 LIQ-60 configuration

The LIQ-60 is configured using LineMan software.

Please refer to Appendix A for instruction on configuring the LIQ-60 with the LineMan software. Commissioning

LIQ-60s must be commissioned after configuration.

5 COMMISSIONING

5.1 Commissioning the LIQ-60

If the LIQ-60 is intended to operate "stand alone", without an associated LIQ-Gateway, it needs to be commissioned directly using a laptop PC and an LIQ-LocalLink local-RF radio, with the LineMan software interface. If the LIQ-60 is associated with an LIQ-Gateway, the LIQ-60 is then commissioned via the LIQ-Gateway.

5.1.1 Pre-commissioning check of the LIQ-60s

Using a laptop running LineMan, connect to each LIQ-60.

Confirm that:

- The internal battery voltage exceeds 2V.
- There is some solar charge current when the solar panel is illuminated.
- Event recording is enabled if required.
- Load logging is enabled if required.
- Line currents are as expected.
- Voltage sensor values are as expected.
- The appropriate LIQ-Gateway (if used) has been assigned as a parent to the LIQ-60.
- The correct phase and group have been assigned
- Location information has been entered

6 INSTALLATION AND REMOVAL



When installing or removing the LIQ-60, if using a hot stick, use only a hot stick rated for use at or above the voltage of the conductor on which the LIQ-60 is installed.

Similarly, if using the glove and barrier method, ensure that the safety equipment used is rated at or above the voltage of the conductor on which the LIQ-60 is installed.

6.1 LIQ-60 installation

The LIQ-60 has been designed for live line installation on Medium and High Voltage (MV and HV) networks (up to 138 kV) using an electric utility hot stick, or using a glove and barrier method with a live line crew. These instructions apply to installation using a hot stick. Each LIQ-60 takes just a few minutes to install.

6.1.1 Pre-installation

Prior to mounting, set the orientation of the LIQ-60's solar panel to maximise sunlight falling onto it. See section *7.2 Solar Panels* for details on determining the direction and angle at which to mount the solar panel.

6.1.2 Mounting

1. Ensure that the LIQ-60 is switched on and configured.
2. Rotate the solar panel so that once the LIQ-60 is in position, it will receive the most sunlight, i.e. facing north when in the southern hemisphere, and south when in the northern hemisphere.
3. Adjust the angle (elevation) of the solar panel as discussed in section *7.2 Solar Panels*.
4. Clamp a hot stick hook onto the sprung slider and pull the hook and slider into the head of the hot stick. This opens the LIQ-60's conductor clamp and the sensing coil.
5. Ensure the LIQ-60 is firmly secured to the hot stick.
6. Install the LIQ-60 by hooking the top portion of its housing over the conductor, so that the channel in the LIQ-60's housing encompasses the conductor.
7. Release the hot stick so that the sprung clamp and sensing coil close, thereby clamping the LIQ-60 to the conductor.
8. Take note of the reference arrow on the bottom of the LIQ-60, and in which compass direction this points, e.g. north, north west etc. This is required to identify the direction of line faults when they occur.
9. Please do not mount the CMS on an insulated conductor

6.1.3 Post-installation checks

1. Check that the LIQ-60 is hanging vertically and has clamped securely onto the conductor.
2. Check that the solar panel direction will maximise exposure to sunlight.
3. Check that the status LEDs are showing correct status: both red LEDs flashing every second (and a status amber flash every 30 sec) if not yet commissioned, or an amber flash every 30 sec when commissioned and reading voltages and current.
4. Check that the status LEDs are showing correct status: both red LEDs flashing every second (and a status amber flash every 30 sec) if not yet commissioned, or an amber flash every 30 sec when commissioned and reading voltages and current.

6.1.4 Removal

1. Clamp a hot stick hook onto the sprung slider and pull the slider into the head of the hot stick. This opens the LIQ-60's conductor clamp and the sensing coil.
2. Remove the LIQ-60 by lifting it slightly so that the conductor slides out of the channel in the LIQ-60's housing.
3. Lower the LIQ-60 carefully, then disengage the hot stick.

7 POWER SYSTEMS

7.1 LIQ-60 Battery

The LIQ-60 is powered by a sealed lead acid battery which provides continuous long term power for remote reporting of events and historic load data. A solar panel mounted on top of the LIQ-60 charges the battery.

The LIQ-60 is delivered with a fully charged battery, but it will slowly discharge during storage. The battery voltage can be determined by using LineMan. (See Appendix A.) If the battery voltage is less than 2.0V then it should be charged before installation. It is recommended that you use a GridSense LIQ-Charger. Alternatively the battery can be charged using the LIQ-60 solar panel. However, charging a flat battery may require optimal sunlight for up to 50 hours.

The battery has a voltage of 2V and a capacity of 10Ah. A typical lifespan is 10 to 15 years.

7.2 Solar Panels

7.2.1 Solar Panel orientation

The LIQ-60's built-in solar panel provides all the energy required by the LIQ-60. The amount of energy produced depends on the following factors:

- The amount of incident solar energy. This varies with the time of day, the season, the distance from the equator (latitude) and the amount of cloud cover.
- The angle at which the sun's rays strike the solar panel.
- The amount of shading (e.g. by trees or nearby structures) or obstruction (e.g. by snow or dust) of the solar panel.

When mounting a solar panel it is important to ensure that it is not in shade from nearby poles, trees etc.

Two adjustments need to be taken into account when positioning the panel, *orientation* and *angle*:

Orientation

This is the direction in which the sun will be for most of the year, i.e. north or south. A panel's performance is optimum when facing towards the equator, that is

- facing north when in the southern hemisphere and
- facing south when in the northern hemisphere.

See Figure 7.

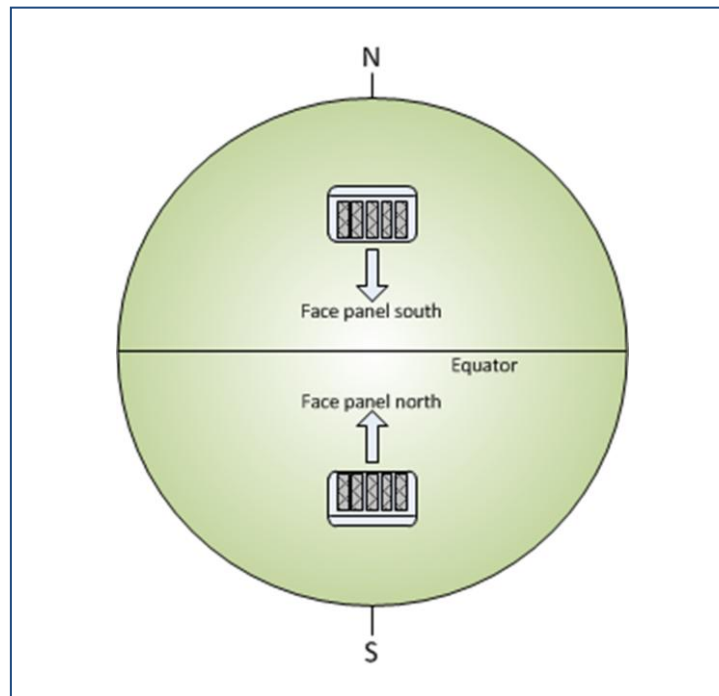


Figure 7: Direction of solar panels in northern and southern hemispheres.

Angle

With regard to angle from the horizontal, the best angle for a solar panel that does not get adjusted for seasonal variation, is 15° more than the latitude where the panel is installed.

For example Sacramento, California, is at approximately 40° N. So the angle from horizontal for the face of the solar panel is $40^\circ + 15^\circ = 55^\circ$. See Figure 8.

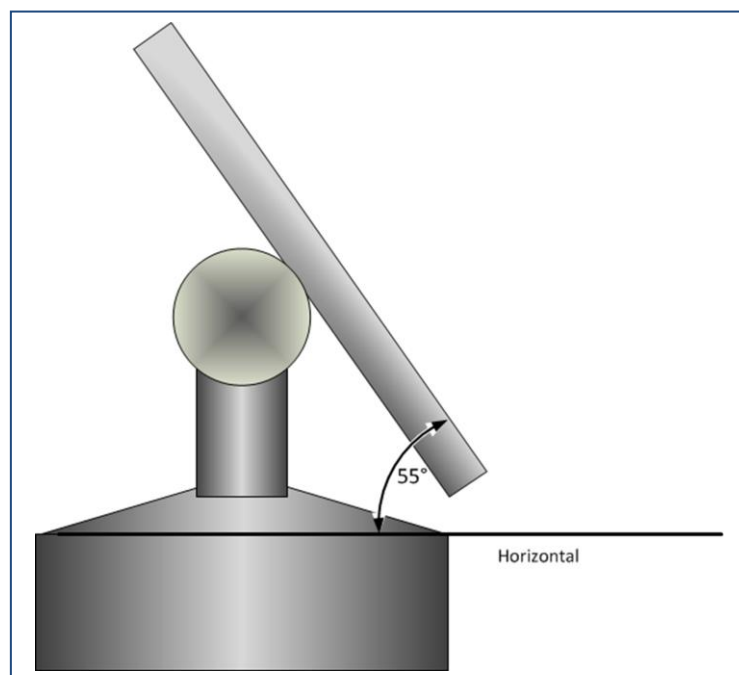


Figure 8: Angle of solar panel from horizontal.

7.2.2 Adjusting the solar panel on the LIQ-60

The solar panel has 2 separate adjustments that need to be made:

- Rotation of the solar panel and its mounting to face toward the equator, and
 - Setting the panel's angle relative to the horizontal.
1. Rotating the solar panel to face the equator:
 - a) Determine the direction that the solar panel must face, i.e. north in the southern hemisphere, or south in the northern hemisphere.
 - b) Hold the LIQ-60 upright and oriented so that the channel that the power conductor will fit into is lined up with the direction of the conductor overhead that it will be installed on.
 - c) Rotate the solar panel so that it faces the determined direction.

The circular base of the solar panel adjusts in pre-set steps of 12°.

Note: In order to avoid twisting the panel's cable, the base has a stop which prevents it from being rotated in a complete circle. If it jams against this stop before reaching the required angle, rotate it in the opposite direction.

2. Setting the panel's angle relative to the horizontal:
 - a) Determine the angle with the horizontal that the solar panel needs to be set to, i.e. latitude + 15°.
 - b) Hold the LIQ-60 upright and adjust the solar panel to this angle relative to the horizontal.

The angle can be set between 25° to 65°, relative to the horizontal. The panel has 6 pre-set stops, in increments of 8°. The following table list the angle increments:

Stop	Angle (°)
Stop 1	25
Stop 2	33
Stop 3	41
Stop 4	49
Stop 5	57
Stop 6	54

Table 2: LIQ-60 Angle Increments

Appendix A - LineMan

A.1 LineMan Overview

LineMan is a software package supplied by GridSense for configuring and communicating with the LineIQ suite of products. It is used during the commissioning phase when setting up an LIQ-60 or LIQ-Gateway, and subsequently when downloading information from the LIQ-60 or LIQ-Gateway to a PC.

A.2 Setting up an LIQ-LocalLink

In order for a PC to communicate with an LIQ-60 or an LIQ-Gateway, it needs to use short range radio. This is achieved by using an LIQ-LocalLink which is a radio modem that plugs into a USB slot on a PC.

The first time you use the LIQ-LocalLink on a PC, it needs to have the correct driver loaded. This driver forms part of Windows 7, so the LIQ-LocalLink should have its driver automatically loaded when it is inserted into a USB slot. Section 3.1 will detail installation procedures for Window 7 whereas Appendix B details installation procedures for Windows XP.

If you are using Windows XP, you can install the driver off the CD containing LineMan:

1. From Windows Explorer, run the setup.exe.
2. Follow the instructions from Windows Install to install the driver.
3. Once the driver is installed you can run LineMan.

A.3 Connecting to the CMS with LineMan

1. Click on the Start → All Programs → Gridsense → LineMan → LineMan to launch the LineMan application.
2. Select the correct COM port as indicated by the **LineMan Connection Window** and click on **Connect to LineTracker**.

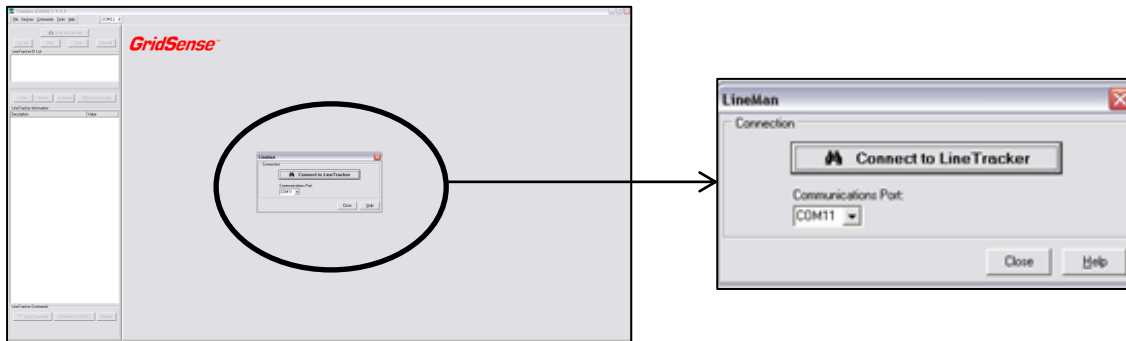


Figure 9: COM port selection

3. The available LIQ-60 within the RF range is displayed under the LineTracker ID List, differentiated by their respective serial number. Melancholy ecstatic

A.4 Displaying LIQ-60 Status/Summary

1. Check the LIQ-60 of interest and click on Summary to display information such as firmware revision, software revision and thresholds.

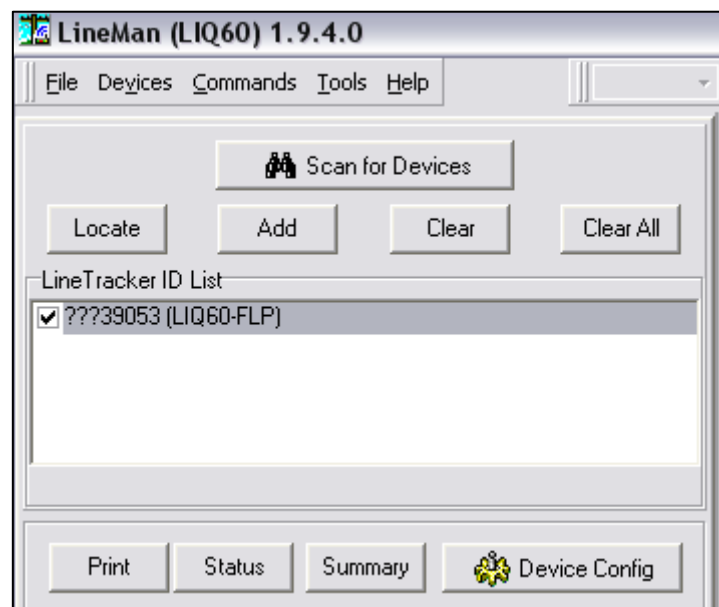



Figure 10: Device List

LineTracker ID List

☒ 11039053 (LIQ60-FLP), ???

Print Status **Summary**  Device Config

LineTracker Information

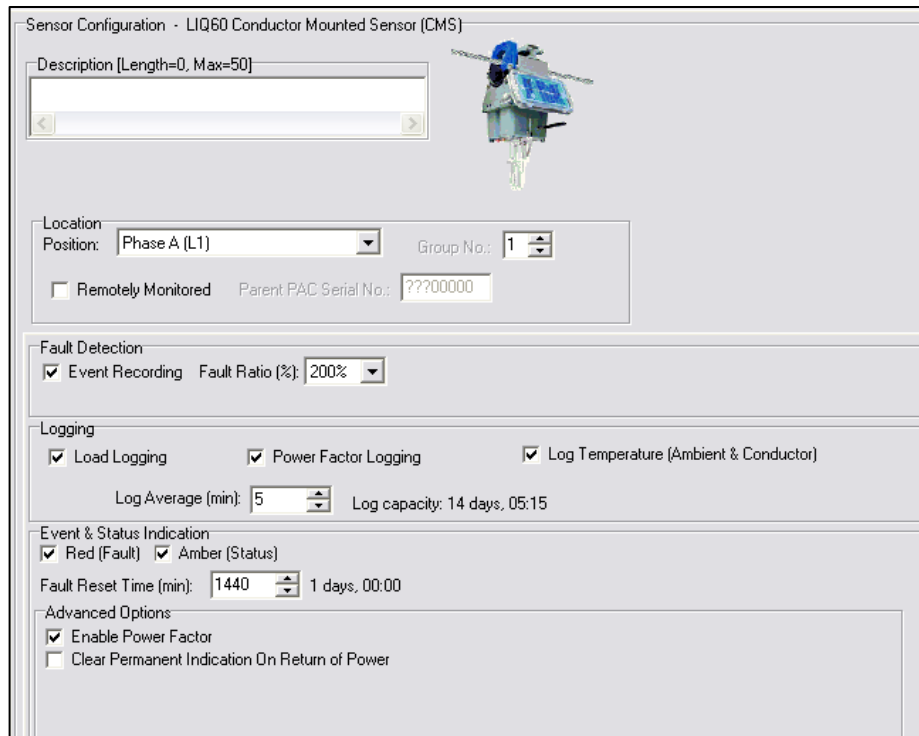
Description	Value
Device Serial Number	11039053
DAQ Firmware Version	Version 15.23
DAQ Hardware Revision	Revision 25E
Current Calibration Coeff (M)	0.041
Current Calibration Coeff (B)	0.323
Temp. Ambient Cal. Coeffs	M= 0.2085, B= 7.6210
Temp. Conductor Cal. Coeffs	M= 0.2101, B= 2.2760
Temp. Conductor Corr. Factor	0.450
Relative High Current Threshold	2
Voltage Off Detection Ratio	50%
Boot Counter	5
Power Factor Calibration Coeff	57067, 0, 1

Figure 11: Displaying LIQ-60 Summary

2. Similarly, click on Status to display information such as charge current, battery voltage and etc.

A.5 Configuring an LIQ-60

1. Click Device Config to display and/or edit the LIQ description and measurement configuration.



Sensor Configuration - LIQ60 Conductor Mounted Sensor (CMS)

Description (Length=0, Max=50)

Location
Position: Phase A (L1) Group No.: 1

☐ Remotely Monitored Parent PAC Serial No.: ???00000

Fault Detection
☒ Event Recording Fault Ratio (%): 200%

Logging
☒ Load Logging ☒ Power Factor Logging ☒ Log Temperature (Ambient & Conductor)
Log Average (min): 5 Log capacity: 14 days, 05:15

Event & Status Indication
☒ Red (Fault) ☒ Amber (Status)
Fault Reset Time (min): 1440 1 days, 00:00

Advanced Options
☒ Enable Power Factor
☐ Clear Permanent Indication On Return of Power

Figure 12: A.5 Configuring a CMS

The user has the following configuration selection:

- a) Enter a 50 character description of the CMS Location into the **Device Description** field.
 - b) Select the **Position Number** of the conductor that the LIQ-60 is on. (e.g. 1-Phase A, 2-Phase B, etc.)
 - c) Select the number of the group that the LIQ-60 is in from the **Group Number** field.
 - d) Select the **Position Number** of the conductor that the LIQ-60 is on. (e.g. 1-Phase A, 2-Phase B, etc.)
 - e) Enable Load Logging
 - f) Enable Fault Detection Event recording
 - g) Enable Power Factor Logging. Should the user select No, the CMS will return only instantaneous data rather than logged readings.
 - h) Enable Temperature Logging.
 - i) Select data polling interval (log average in minutes). Selecting a higher polling rate will decrease the log capacity, as the available memory will reduce. However, the most recent data is always retained.
2. Click Apply Configuration to apply any configuration changes
 3. Click on Save Config Profile to Disk to save the config settings.

A.6 CMS Data Download

1. Click the Data Download tab button on the LineTracker Command windowpane. The Read All Window pane will pop-up. The user can choose to download either Event Data or both Events and Load Logging Data. Select the required option and click on Next to proceed.

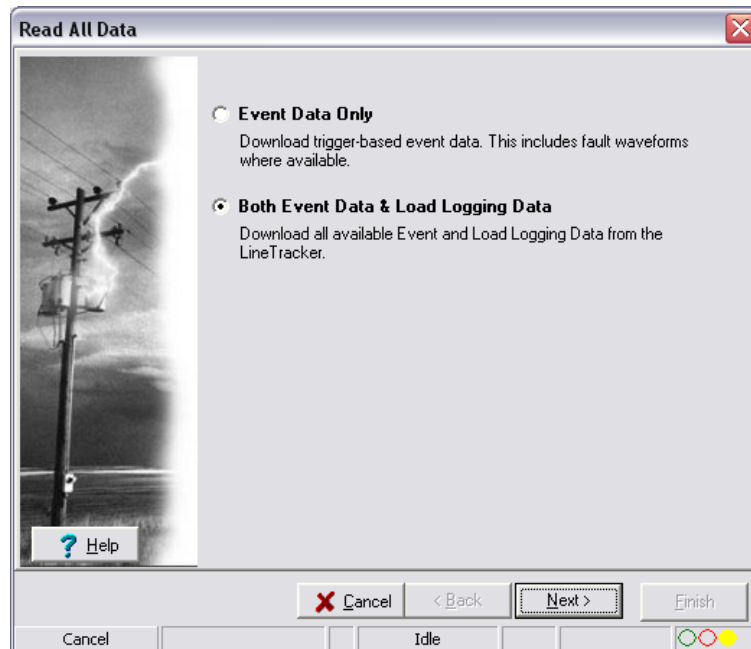


Figure 13: Data Download Option

2. Save the data file to the preferred location as prompted by the window. The user can monitor the download progress from the task bar. The status will change to Done for a successful download. Click on Finish to close the Read All Data window.

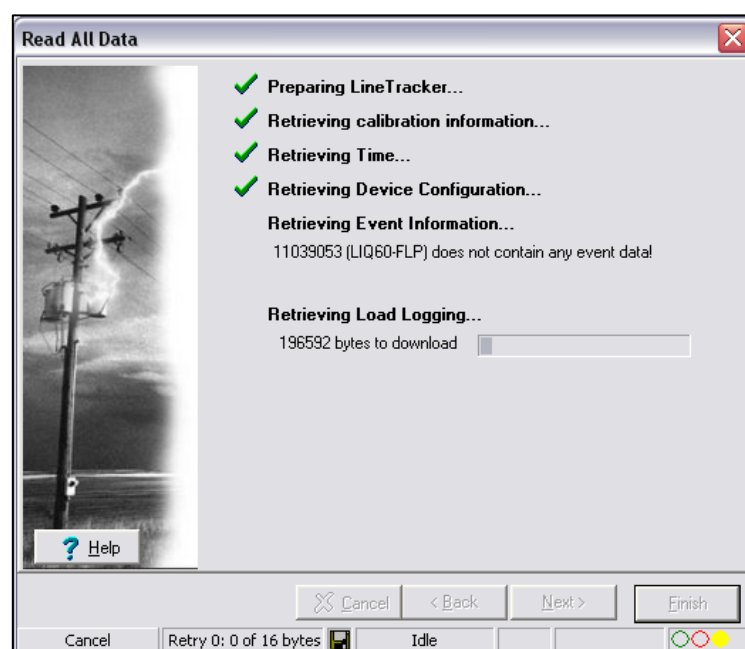


Figure 14: File Download

Appendix B - Window XP Installation

The driver for the LIQ-LocalLink is provided on the LineMan installation CD-ROM. The driver can also be downloaded from the Digi® website on their web-page for the *XStick USB 802.15.4*, at <http://www.digi.com/support/productdetl.jsp?pid=3564&osvid=0&s=444&tp=1>.

To install by running the driver file:

1. From the CD-ROM or downloaded driver file, run the file CDM20600.exe
2. Install the driver as per the Windows installation wizard, select "No, not this time" on the 1st screen:



Figure 15: Windows XP driver installation dialog screen 1

3. At the next screen, insert the CD-ROM and select "Install the software automatically":

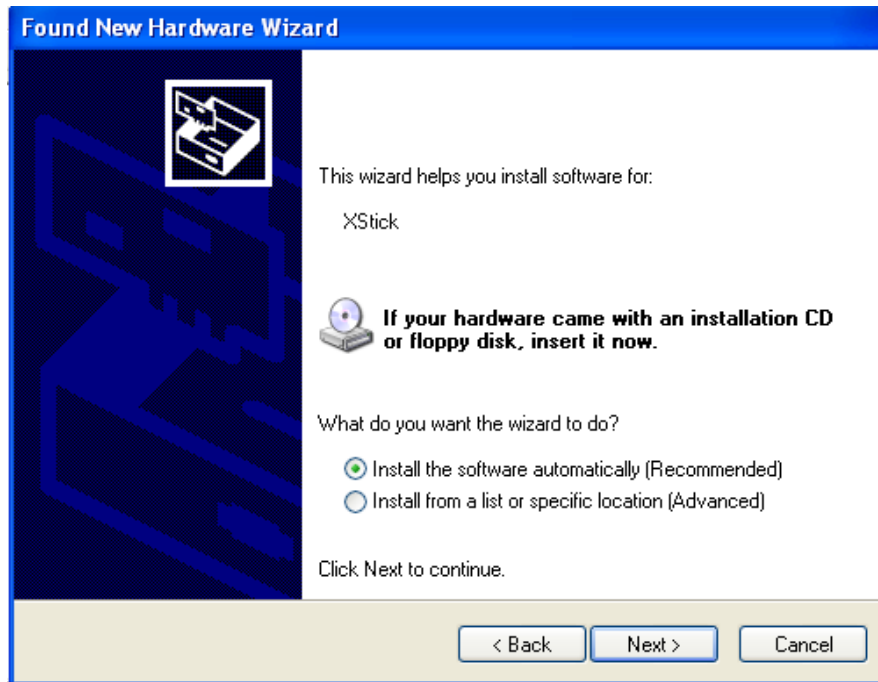


Figure 16: Windows XP driver installation dialog screen 2

The wizard will look for the driver and install it.

Follow the steps until the wizard completes:

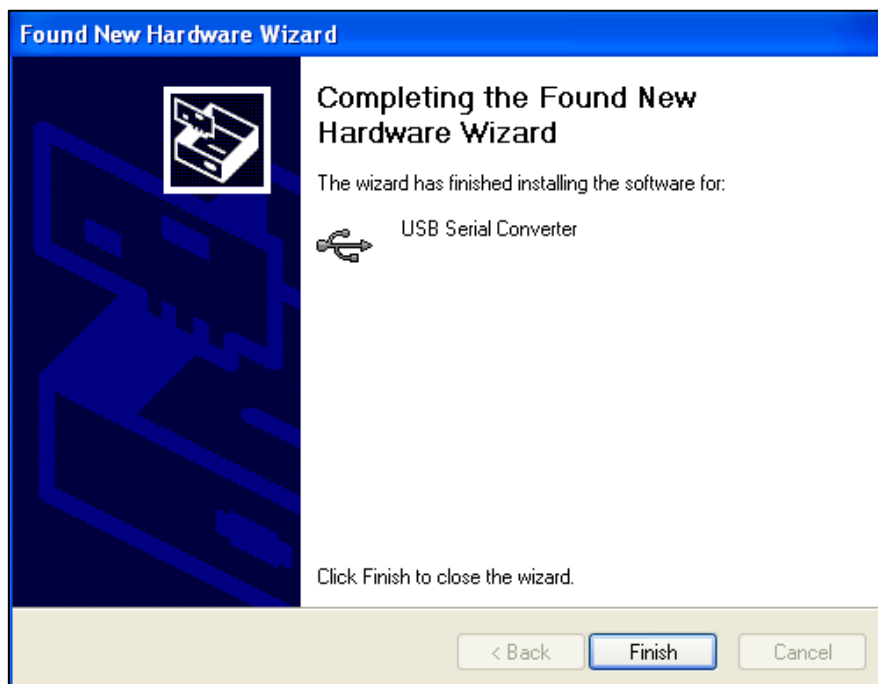


Figure 17: Windows XP driver installation dialog screen 3

Note: Depending on setup, this may be a 2-step process, the 1st wizard installing an XStick as a "USB serial convertor", then the 2nd Wizard installing a "USB serial port."

The COM port on the PC that the LIQ-LocalLink is assigned to can be determined as follows (you will need to know the COM port number to set up communications between LineMan and the LIQ-LocalLink):

4. On the Windows task bar, click the **Start** button, then select **Control Panel** > **System** > **Device Manager**:

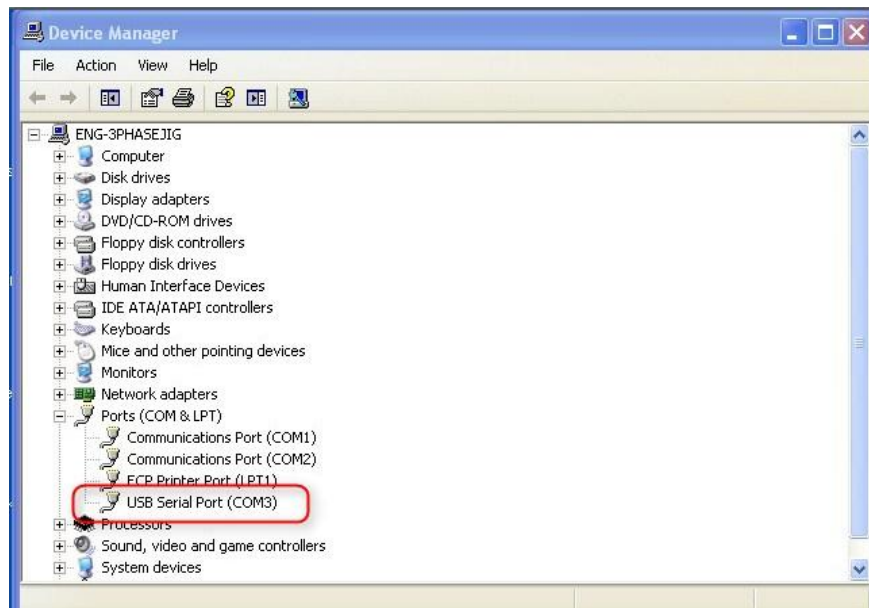


Figure 18: Device Manager showing USB serial COM port number

In the example above, the USB serial port is COM port 3.

An LED inside the LIQ-LocalLink's translucent casing flashes about once a second to indicate it is powered up.

Appendix C

C.1 LIQ-60 specifications

Application		
Medium V / High V overhead distribution network sensing and measurement, 4 wire, multiple grounds, 3 wire, single phase, SWER and mixed circuit installations.		
Item	Description	
Interfaces		
Communication	Local-RF Communication	RF range 30m (100ft) line of sight.
Status indicators	Three high intensity LEDs, 2 x red & 1 x amber	
Sensing and logging		
Line voltage	5kV to 138kV	
Frequency	45 to 65Hz	
Current sensor	Fault detection range: 5A – 25kA Load logging range: 1A – 25kA (Accuracy +/- 5% or +/- 1A, whichever is greater).	
Trigger principle	Proprietary algorithms based on current and voltage ratios, adaptive to the line signature i.e. load and voltage history. Inrush restraint.	
Memory	Total Memory = 196 Kbytes available. Event data = 32 Kbytes Load log = 164 Kbytes (optional)	
Logged data	Time stamped, pre and post voltage status, pre and post current values, 200ms of fault current waveform (60ms pre and 140ms post fault), 2nd harmonic calculations.	
Mechanical and Power		
Battery specifications	4 x 2V, 2.5Ah rechargeable SLA Battery, 10 years life typ.	
Power source	Dual power circuitry – Solar panel and internal SLA Battery. Battery specifications: 4 x 2V 2.5Ahr creating a 10Ahr battery pack. Solar charging max 150mA gives 100% charge in approx. 17 days. External Charging max 5A, charge time approx. 3 hours.	
Current use	Normal operation (No RF Transmission) = 5mA.	
Clamping mechanism	A spring loaded conductor clamp. Mounting and de-mounting by means of hot stick.	
Conductor size	Approx. 6mm (0.25 inch) – 32mm (1.25 inch) diameter.	
Weight	2kg (4.4lb)	
Dimensions	Height: 315mm (12.4 in), Depth: 180mm (7 in), Width: 140mm (5.5 in)	
Environmental		
Temperature ranges	Ambient operating range	- 40°C to +70°C (- 40°F to +160°F)
	Range for accuracy	- 20°C to +65°C (- 4°F to +120°F)
	Conductor operating range	- 40°C to +130°C (- 40°F to +265°F)
	Conductor, guaranteed accuracy	- 20°C to +90°C (- 4°F to +195°F)
Humidity range	0 % to 100 %	

